Accuracy Assessment of Current Gravity Field Models

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ABSTRACT

Within this decade of the geopotential, it is envisioned that a significant number of improved gravity field models will be and are already available, primarily due to measurements with unprecedented accuracy from the advanced gravity field mapping missions, including CHAMP, GRACE and GOCE. Robust and independent accuracy assessment of these gravity field solutions are needed to take full advantage of the new measurements. In this study, we present preliminary results for the evaluations of several currently available gravity field solutions and their solution covariance matrices using independently obtained data sets, some of which have not been previously used. The available gravity field models, in addition to the EGM96 model, including the CHAMP and GRACE candidate prelaunch models and the proposed reference geoid model for Jason-1: GRIM5C1, TEG-4, and PGM2000A.

1. INTRODUCTION

In order to test the performance of EGM96 ("solved" up to degree 70, complete to degree 360) [Lemoine et al., 1997] PGM2000A (same as EGM96) [Pavlis et al., 2000], GRIM5C1 ("solved" up to 120) [Gruber et al., 2000], and TEG4 ("solved" up to 200) [Tapley et al., 2001] models in terms of the geoid undulation and gravity anomaly, an independent data set including GPS and Doppler leveling, and gravity anomaly have been compiled and compared with the models over land. Some of these data have not been previously used to evaluation gravity field models. The dynamic ocean topographies computed using the gravity models and T/P altimeter data are also compared with the POCM-4B ocean model. The available solution variance/covariance matrices, EGM96 (complete to degree 70), GRIM5C1 (complete to 120), and TEG4 (complete to 200) are analyzed to evaluate their respective predicted geoid accuracy. Finally, the accuracy of the lumped-long wavelength component of the models is evaluated using orbit fits of tracking data to various Earth-orbiting geodetic satellites.

2. DATA AND METHODS

2.1 Comparison with GPS/leveling and Doppler levelling data

GPS and Doppler positioning data provides the ellipsoidal height, **h**, while the leveling data gives the orthometric height, **H**, from the local vertical datum. By differencing these geometric data and correcting the vertical datum shifts, **d**, the geoid undulation, **N**, referred to the certain global datum like WGS84, can be obtained at each observation point. The geometrically derived geoid heights are compared with the values derived from geopotential models. The pictorial concept is described at the following figure 1.

GPS/leveling data from five countries (US, Canada, Australia, Europe, and Germany) and the world-wide Doppler Levelling data are obtained and the geoid height are computed at these points. Figure 2 shows distribution of these data.

Figure 1. GPS/leveling concept
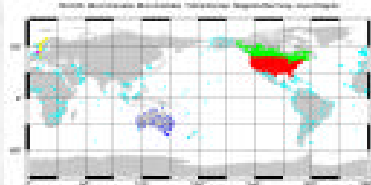
Before computing the geoid height from different geopotential models, TEG4 and GRIM5C1 models are argumented with the coefficients from the PGM2000A model. That is, the coefficients of PGM2000A from degree and order 201 to 360 are included in TEG4 model, and the coefficients from degree and order 121 to 360 are included in GRIM5C1 model. We should add that tests have been conducted using lower degree field (e.g., 120) and the relative performance (i.e., rms) for the models is the same.

The statistical values, mean and standard deviations, of geoid height differences between GPS/leveling or Doppler data and geopotential models are computed each countries and described in following tables. That is, tables show statistics of **h** (GPS or Doppler) – **H** (leveling) – **N** (model with degrees higher than 2).

Figure 2. GPS/leveling and Doppler data distribution

• Zero degree undulation and local vertical datum shift in mean differences of GPS/leveling tests are corrected. Their effects are –108cm (–53cm ~ –55cm) and –11cm (–53cm + 42cm) for the case of US/Canada and Australia, respectively.

2.2 Comparison with gravity anomaly data

Gridded data (15'x15' mean free-air gravity anomalies from different sources) are compared with free-air gravity anomalies derived from different data sources/models. The following explains briefly the source and number of data.

Arctic Data (preliminary 30' data sets by S. Kenyon):
KMS: Altimetry derived gravity anomalies (3550 pts.)
GSCANRUS: Surface, marine, and airborne observations from Greenland, Scandinavian, and Russian gridded data (14827 pts.)
CANADA: Data derived from surface gravity measurements (23730 pts.)
GREENLAND: Downward continued data from airborne observations (10786 pts.)
NRL: Downward continued data from airborne observations (50820 pts.)
VNIIO: Gridded Russian data (7991 pts.)

Also, gravity models are tested with **ERS-1/2** derived gravity anomaly based on data covered over latitude (73N~81.45N) and longitude (165E~225E) with the resolution of 1.5'(lat) x7.5'(lon) [Laxon and McAdoo, 1999].

Other data are **Chinese** 30'x30' gridded mean gravity anomalies [Lu et al., 1999]. These data cover the area (20~45N, 75~125E). The number of data is 3226 pts.

Geopotential Models	KMS(3550pts.)		GSCANRUS(14827pts.)		CANADA(23730pts.)	
	mean(mgal)	s.d.(mgal)	mean(mgal)	s.d.(mgal)	mean(mgal)	s.d.(mgal)
EGM96(360)	-0.61	6.94	-0.46	11.20	0.06	14.61
PGM2000A(360)	-0.70	7.10	-0.34	11.23	0.03	14.61
GRIM5C1(120) + PGM2000A(121~360)	-0.77	7.56	-0.38	11.49	0.72	15.32
TEG4(200) + PGM2000A(201~360)	-0.07	7.35	-0.29	11.93	-0.06	15.86

Geopotential Models	GREENLAND(10786pts.)		NRL(50820pts.)		VNIIO(7991pts.)	
	mean(mgal)	s.d.(mgal)	mean(mgal)	s.d.(mgal)	mean(mgal)	s.d.(mgal)
EGM96(360)	-0.59	15.45	0.85	18.94	1.29	22.56
PGM2000A(360)	-0.62	15.43	0.92	18.97	1.06	22.54
GRIM5C1(120) + PGM2000A(121~360)	0.65	16.80	5.29	25.14	1.06	25.33
TEG4(200) + PGM2000A(201~360)	-0.62	17.48	-0.79	19.68	3.58	23.67

Geopotential Models	China(3226pts.)		ERS-1/2(162578pts.)	
	mean(mgal)	s.d.(mgal)	mean(mgal)	s.d.(mgal)
EGM96(360)	3.45	22.66	-0.07	13.25
PGM2000A(360)	3.46	22.63	0.00	13.25
GRIM5C1(120) + PGM2000A(121~360)	3.61	23.50	-0.16	13.84
TEG4(200) + PGM2000A(201~360)	3.49	22.66	-0.10	14.01

2.3 Comparison with POCM-4B dynamic ocean topography (DOT)

The mean sea surface averaged in 0.25°×0.25° grid is computed with TOPEX data based on Cycles 10-142 (Dec., 1992- July, 1996) from the OSU stackfile compiled by Y. Yi. Using the mean sea surface and various model-derived geoid undulations, the dynamic ocean topography (DOT) models (figures below) computed for each gravity field. The statistics of difference between model-derived DOT and POCM-4B DOT model (Nmax=360) are given in the following table.
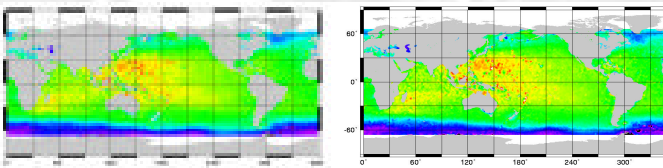

Figure 3. T/P MSS - Geoid height of EGM96 (Nmax=360)

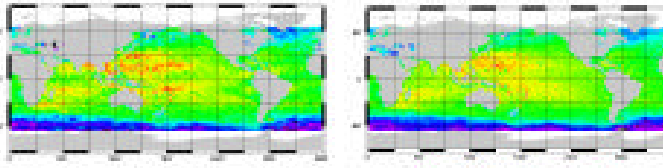**Figure 4.** T/P MSS - Geoid height of PGM2000A (Nmax=360)

Figure 5. T/P MSS - Geoid height of GRIM5C1 (Nmax=120) + PGM2000A (121~360)

Figure 6. T/P MSS - Geoid height of TEG4 (Nmax=200) + PGM2000A (201~360)

2.4 Comparison of the geoid undulation accuracies predicted by covariance matrices (Nmax=70)

The covariance matrices of EGM96, GRIM5C1, and TEG4 models are used to generate the predicted accuracy of geoid undulations with the 10°×10° resolution. The following table and figures show the statistical information and values of geoid height accuracy derived from each model. According to GPS/leveling test, TEG4 performs better than EGM96 over US and Australia areas. The same conclusion is found by looking at their covariance derived geoid undulation accuracy. That is, EGM96 and TEG4 covariance (70x70) tell us that TEG4 provides better geoid undulation over US and Australia areas. However, EGM96 performs better in global sense. For the GRIM5C1 covariance (70x70), the "satellite" effect (i.e., zonal band structures) seems to be dominant which could be attributable to the fact that satellite data have a heavier weight relative to the surface data. However, the full GRIM5C1 covariance (120x120) computed geoid undulation errors provide similar error pattern as the other models.
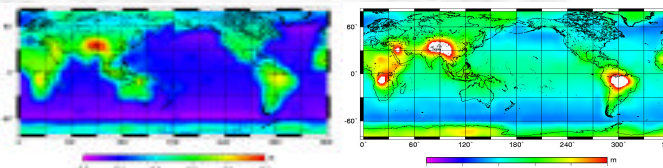

Figure 7. Geoid height accuracy predicted by EGM96 covariance (Nmax=70) with 10°×10° resolution

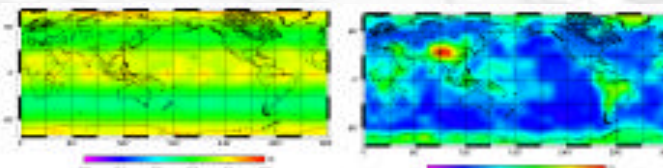**Figure 8.** Geoid height accuracy predicted by TEG4 covariance (Nmax=70) with 10°×10° resolution

Figure 9. Geoid height accuracy predicted by GRIM5C1 covariance (Nmax=70) with 10°×10° resolution

Figure 10. Geoid height accuracy predicted by GRIM5C1 covariance (Nmax=120) with 10°×10° resolution

2.5 Orbit tests with various models (Nmax=99)

3. CONCLUSION

EGM96(360) or PGM2000A(360) models perform best over the Artic and ocean areas when they are compared with gravity anomaly data and POCM-4B model. However, TEG4(200) model argumented with PGM2000A performs well in the GPS/leveling test over some of the land areas and for orbit test. GRIM5C1(120) model performs well on many of the orbit tests. The results of this study, especially the tests associated with orbit fits and anomaly comparisons, would at times conflicts with conclusions derived from model developers. It is therefore critically important to compile more independent data sets and developing additional tests for the purpose of robust evaluations of the fidelity of the upcoming new gravity field solution models using CHAMP, GRACE and GOCE data.